Rec'd PCT/PTO 11 JAN 2002

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: A-7751

U S APPLICATION NO (IF KNOWN, SEE 37 CFR): 10/030084

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP 00/05934	27.07.00 (27 June 2000)	13.07.99 (13 July 1999)

TITLE OF INVENTION
PRODUCTION OF LINES OF LIGHT AS AN AID TO POSITIONING A ROBOT

APPLICANT(S) FOR DO/EO/US
Vitalij LISSOTSCHENKO and Alexei MIKHAILOV

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☐ Other items or information

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
10/030084	PCT/EP 00/05934	A-7751

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24. The following fees are submitted:.	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	11 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,020.00**	
☒ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$510.00**	
SUBTOTAL =				**$510.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$130.00**	
TOTAL NATIONAL FEE =				**$640.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$640.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$640.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **08-2455** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Stewart L. Gitler
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Stewart L Gitler
SIGNATURE

Stewart L. Gitler
NAME

31,256
REGISTRATION NUMBER

January 10, 2002
DATE

5000 5960

#6/B

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Vitalij LISSOTSCHENKO and
Alexei MIKHAILOV

Serial No.: **10/030,084**

Group Art Unit:

Examiner:

Filed : **January 11, 2002**

For : **PRODUCTION OF LINES OF LIGHT AS AN AID TO POSITIONING A ROBOT**

PRELIMINARY AMENDMENT B

Commissioner of Patents and Trademarks
Washington, D.C. 20231

ATTN: PCT BRANCH

Sir:

Please amend the above-identified application, as follows:

In the Specification:

Please replace paragraphs 1-21, with the amended paragraphs provided.

In the Abstract:

Please add the attached Abstract of the Disclosure.

Remarks

Applicants have amended the English translation of the application to conform with U.S. application practice. No new matter has been added, nor have any changes been made to overcome or address prior art. A marked-up copy and clean copy of the changes have been provided. An Abstract has been added.

A signed Declaration/Power of Attorney is also enclosed.

Respectfully submitted,

Stewart L. Gitler
Reg. 31,256

March 5, 2002
Hoffman, Wasson & Gitler, P.C.
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Attorney Docket: A-7751.PAMB/cat

--ABSTRACT OF THE DISCLOSURE

This invention relates to a device for producing lines or groups of lines of electromagnetic radiation of the optical spectral range in a definable area of space. The lines or groups of lines can be used as positioning aids or geometry detection aids, and they include at least one conversion unit which is at least partially transparent to the electromagnetic radiation used, and which can convert the electromagnetic radiation passing through it, especially coherent radiation or laser radiation, such that the electromagnetic radiation forms at least one line or group of lines in a given three-dimensional area.--

PRODUCING LINES OF LIGHT FOR POSITIONING ASSISTANCE FOR ROBOTS

Background of the Invention

[0001] This invention relates to a device for producing lines or groups of lines of electromagnetic radiation of the optical spectral range in a definable area of space. The lines or groups of lines can be used as positioning aids or geometry detection aids, and they include at least one conversion unit which is at least partially transparent to the electromagnetic radiation used, and which can convert the electromagnetic radiation passing through it, especially coherent radiation or laser radiation, such that the electromagnetic radiation forms at least one line or group of lines in a given three-dimensional area.

[0002] A device of this type is used, for example, to give to a robot a positioning aid for machining of a workpiece, or to make available to the robot a recognition aid for the contour or the geometry of a workpiece. Generally, the electromagnetic radiation is laser light which passes through the conversion unit into the stipulated three-dimensional area located, for example, on the workpiece such that on the workpiece for the robot, recognizable groups of lines are copied in the form of a planar orthogonal grid. Using these groups of lines, made for example as grids, the robot is enabled to machine the workpiece at given points.

[0003] Conversion units in the past are diffractive elements such as holograms which can diffract parts of the laser light penetrating the conversion unit, such that in the given three-dimensional area, for example, on the workpiece, lines, or for example, grid-shaped groups of lines form. One defect, in the past embodiments of the conversion unit using diffractive elements, is that a substantial portion of the electromagnetic radiation is diffracted into undesirable orders so that generally far less than 50% of the electromagnetic radiation incident on the conversion unit contributes to producing lines or groups of

lines. Furthermore, when the conversion unit is equipped with diffractive elements, it is disadvantageous that only very small widening angles can be achieved, so that only in a relatively small range of solid angles behind the conversion unit, can lines or groups of lines be produced.

[0004] The object of this invention is to devise a device of the initially mentioned type which is made to be more efficient.

SUMMARY OF THE INVENTION

[0005] This is achieved as depicted in the invention, in that the conversion unit includes at least one refractive element. By refraction of the radiation passing through the conversion unit, on at least one optically functional interface of the refractive element, at least one line or group of lines is formed in the given three-dimensional area. When using a refractive element, much higher efficiencies of almost 100% can be achieved. Furthermore, refractive elements make it possible to dramatically broaden the electromagnetic radiation incident on the conversion unit, so that the desired lines, or groups of lines, can be formed in an essentially larger range of solid angles behind the conversion unit.

[0006] To do this, the optically functional interface of at least one refractive element can have a freely selectable configuration which is suitable for the lines, or line groups, to be produced. It is, for example, possible to divide the optically functional interface of at least one refractive element into segments. In this case, the segments can have the same size and can be shaped to be identical.

[0007] According to one preferred embodiment of this invention, the individual segments can have a cylinder lens geometry, there being, preferably, two groups of segments with cylinder axes of cylindrical geometry perpendicular to one another. The cylinder lens geometry of the individual segments can be a spherical, or an aspherical, cylinder lens geometry.

Especially in the choice of these cylinder lens geometries, is it possible to widen the electromagnetic radiation passing through the conversion unit behind the latter into a solid angle of up to, or even more than, 180°. For example, groups of crossed lines can be formed, by the arrangement of individual segments of the optically functional interface, as cylinder lens segments with cylinder axes perpendicular to one another and can form a grid-like structure, as for example, a planar orthogonal grid with a correspondingly array-like arrangement of the refractive elements.

[0008] It is possible, as depicted in the invention, for the produced lines to be straight or even curved lines. Furthermore, it is possible for the generated groups of lines to be crosses, triangles, polygons or grids, and the lines which form the individual groups of lines can be at a right, or at a non-right angle to one another.

[0009] According to one preferred embodiment of this invention, the generated lines or groups of lines are curved such that upon incidence on a curved surface of a workpiece in a given three-dimensional area on this workpiece, they form a planar structure, especially a planar, orthogonal grating. It is, for example, conceivable that in machining robot machines, the workpiece removes material from the workpiece with the aid of the aforementioned inherently curved grid structure until the sensors of the robot detect that the line structure which is incident on the machined curved surface of the workpiece forms a planar orthogonal grid. The conversion unit, encompassed by the device as depicted in the invention, causes distortion of the traversing electromagnetic radiation which is distorted by a correspondingly curved workpiece such that a clearly detectable structure like a planar orthogonal grid is formed.

[0010] It is possible for the device to include a source for producing electromagnetic radiation, especially a laser light source. The device together with the laser light source can be

used either as a separate unit or can, for example, be installed in a corresponding robot for machining of workpieces.

[0011] It is also possible to use one such device for process monitoring, for example, to monitor a welding process, here especially, an application in conjunction with CMOS cameras is suitable, because these CMOS cameras have much higher dynamics so that among others both the welding point and also its vicinity can be better recognized, so that, for example, the lines, or groups of lines, imaged on the workpiece to be welded can be better recognized by the welding unit, or the process monitoring unit. Other possible applications of a device as depicted in the invention are in the area of surface analysis or three-dimensional assignment, especially tracking of a system.

Brief Description of the Figures

[0012] Other advantages and features of this invention become clear from the following description of preferred embodiments with reference to the attached Figures:

[0013] Figure 1 shows a perspective view of a conversion unit as claimed in the invention; and

[0014] Figure 2 shows a plan view of four groups of lines of electromagnetic radiation which can be produced using the conversion unit as shown in Figure 1 in a predefinable three-dimensional area.

Detailed Description of the Invention

[0015] First, reference is made to Figure 1. The sample embodiment of a conversion unit 1 as depicted in the invention, as shown in Figure 1, is composed of four identical refractive elements 2. In the embodiment shown, the refractive elements 2 are each of the same size and each have a planar quadratic entry surface for the electromagnetic radiation, the four entry surfaces being located bordering one another such that the four

quadratic planar entry surfaces of the refractive elements form a continuous square.

[0016] One optically functional interface 3, which is used as the exit surface for the electromagnetic radiation, made for example as a laser beam is opposite the planar entry surface of each of the refractive elements 2. In the embodiment shown, the optically functional interfaces 3 are each divided into four segments 4. In the embodiment shown, the segments being chosen such that the refractive element 2 represents a regular four-sided pyramid with curved side surfaces. The curvature of the segments 4 of the optically functional interface 3 is chosen in the embodiment shown such that the segments 4 opposite one another are sections of the same cylinder jacket. Here the cylinder axes of adjacent segments 4 are perpendicular to one another at the same time. Each of the refractive elements 2 thus include, in the embodiment shown, an optically functional interface 3 which is composed of four segments 4 which are used as cylinder lenses. These segments 4 which are used as cylinder lenses touch one another at the tip of the aforementioned regular polygonal pyramid with curved side surfaces.

[0017] With corresponding transparency of the conversion unit, shown in Figure 1, to the electromagnetic radiation incident on the conversion unit 1, in the three-dimensional area which is located preferably at the distance of the focal length of the cylinder lens-like segment 4 from the conversion unit, there is an arrangement of groups 5 of lines which is apparent from Figure 2. Each of the groups 5 of lines include two lines 6, 7 which cross one another at an angle of 90°. Each of the lines 6 and 7 represents a combined focal line of two segments 4 of an optically functional interface 3 of one of the refractive elements 2, the two segments 4 being opposite one another. The vertical position of the cylinder axes of adjacent segments 4 of refractive elements 2 yields the cross shape of each of the groups 5 of lines. In particular, the right angle between the

lines 6 and 7 follows from the cylinder axes of adjacent segments 4 being perpendicular to one another.

[0018] If the cylinder axes of adjacent segments are not perpendicular to one another, there is a group of lines in which the individual lines cross at an angle which is not equal to a right angle. It is possible as depicted in the invention to choose different geometries of the individual segments. For example, aspherical cylinder geometries can be used, or even largely free-form surface geometries. It is also possible to divide the optically functional interfaces into more or less than four segments.

[0019] In this way, not only crossed groups of lines which according to Figure 2 overall yield a grid, but also lines which yield a triangle or lines which yield a polygon and which are then combined with the corresponding other groups of lines into patterns can be produced. It is also possible to execute the individual lines as curved lines, depending on the geometrical configuration of the individual segments or the individual optically functional interfaces of the conversion unit.

[0020] Furthermore, it is possible to produce for example grid-shaped groups of lines which then become apparent only as an orthogonal grid structure when the laser radiation passing through the conversion unit in the given three-dimensional area is incident on a curved surface of a workpiece. One such structure which appears as an orthogonal grid structure in projection onto a curved surface could be used, for example, within the framework of machining processes on the aforementioned workpiece. In particular, a robot which shapes a workpiece could remove material in a controlled manner on the workpiece until the light passing through from the conversion unit to the workpiece yields an orthogonal planar grid. In this case, the workpiece has the desired curved surface on which the projected groups of lines yield an orthogonal planar grid.

[0021] It is furthermore possible for the device for producing lines or groups of lines to be integrated into a robot which

machines workpieces so that both a laser light source and also a corresponding conversion unit are encompassed by the robot. Alternatively, there can be a separate device for producing lines or groups of lines which includes a laser light source and a conversion unit and accordingly must be arranged at a given interval to the workpiece which is to be machined by the robot.

"Marked-Up Specification"

PRODUCING LINES OF LIGHT FOR POSITIONING ASSISTANCE FOR ROBOTS

Background of the Invention

[0001] This invention relates to a device for producing lines or groups of lines of electromagnetic radiation of the optical spectral range in a definable area of space[, and the]. The lines or groups of lines can be used as positioning aids or geometry detection aids, [comprising] and they include at least one conversion unit which is at least partially transparent to the electromagnetic radiation used, and which can convert the electromagnetic radiation passing through it, especially coherent radiation or laser radiation, such that the electromagnetic radiation forms at least one line or group of lines in a given three-dimensional area.

[0002] A device of this type is used, for example, to give to a robot a positioning aid for machining of a workpiece, or to make available to the robot a recognition aid for the contour or the geometry of a workpiece. Generally, the electromagnetic radiation is laser light which passes through the conversion unit into the stipulated three-dimensional area located, for example, on the workpiece such that on the workpiece for the robot, recognizable groups of lines are copied in the form of a planar orthogonal grid. Using these groups of lines, made for example as grids, the robot is enabled to machine the workpiece at given points.

[0003] Conversion units in the [prior art] past are diffractive elements such as holograms which can diffract parts of the laser light penetrating the conversion unit, such that in the given three-dimensional area, for example, on the workpiece, lines, or for example, grid-shaped groups of lines form. One defect, in the past [embodiment] embodiments of the conversion unit using diffractive elements, is that a substantial portion of the electromagnetic radiation is diffracted into undesirable orders so that generally far less than 50% of the electromagnetic

radiation incident on the conversion unit contributes to producing lines or groups of lines. Furthermore, when the conversion unit is equipped with diffractive elements, it is disadvantageous that only very small widening angles can be achieved, so that only in a relatively small range of solid angles behind the conversion unit, can lines or groups of lines be produced.

[0004] The object of this invention is to devise a device of the initially mentioned type which is made to be more efficient.

SUMMARY OF THE INVENTION

[0005] This is achieved as [claimed] depicted in the invention, in that the conversion unit [comprises] includes at least one refractive element[, by]. By refraction of the radiation passing through the conversion unit, on at least one optically functional interface of the refractive element, at least one line or group of lines is formed in the given three-dimensional area. When using a refractive element, much higher efficiencies of almost 100% can be achieved. Furthermore, refractive elements make it possible to [much more] dramatically broaden the electromagnetic radiation incident on the conversion unit, so that the desired lines, or groups of lines, can be formed in an essentially larger range of solid angles behind the conversion unit.

[0006] To do this, the optically functional interface of at least one refractive element can have a freely selectable configuration which is suitable for the lines, or line groups, to be produced. It is, for example, possible to divide the optically functional interface of at least one refractive element into segments. In this case, the segments can have the same size and can be shaped to be identical.

[0007] According to one preferred embodiment of this invention, the individual segments can have a cylinder lens geometry, there being, preferably, two groups of segments with

cylinder axes of cylindrical geometry perpendicular to one another. The cylinder lens geometry of the individual segments can be a spherical, or an aspherical, cylinder lens geometry. Especially in the choice of these cylinder lens geometries, is it possible to widen the electromagnetic radiation passing through the conversion unit behind the latter into a solid angle of up to, or even more than, 180°. For example, groups of crossed lines can be formed, by the arrangement of individual segments of the optically functional interface, as cylinder lens segments with cylinder axes perpendicular to one another and can form a grid-like structure, as for example, a planar orthogonal grid with a correspondingly array-like arrangement of the refractive elements.

[0008] It is possible, as [claimed] depicted in the invention, for the produced lines to be straight or even curved lines. Furthermore, it is possible for the generated groups of lines to be crosses, triangles, polygons or grids, and the lines which form the individual groups of lines can be at a right, or [an] at a non-right angle to one another.

[0009] According to one preferred embodiment of this invention, the generated lines or groups of lines are curved such that upon incidence on a curved surface of a workpiece in a given three-dimensional area on this workpiece, they form a planar structure, especially a planar, orthogonal grating. It is, for example, conceivable that [a] in machining robot machines, the workpiece [or for example] removes material from the workpiece with the aid of the aforementioned inherently curved grid structure until the sensors of the robot detect that the line structure which is incident on the machined curved surface of the workpiece forms a planar orthogonal grid. The conversion unit, encompassed by the device as [claimed] depicted in the invention, [thus] causes distortion of the traversing electromagnetic radiation which is distorted by a correspondingly curved workpiece such that a clearly detectable structure like a planar orthogonal grid is formed.

[0010] It is possible for the device to [comprise] include a source for producing electromagnetic radiation, especially a laser light source. The device together with the laser light source can be used either as a separate unit or can, for example, be installed in a corresponding robot for machining of workpieces.

[0011] It is also possible to use one such device for process monitoring, for example, to monitor a welding process, here especially, an application in conjunction with CMOS cameras [seeming to be] is suitable, because these CMOS cameras have much higher dynamics so that among others both the welding point and also its vicinity can be better recognized, so that, for example, the lines, or groups of lines, imaged on the workpiece to be welded can be better recognized by the welding unit, or the process monitoring unit. Other possible applications of a device as [claimed] depicted in the invention are in the area of surface analysis or three-dimensional assignment, especially tracking of a system.

Brief Description of the Figures

[0012] Other advantages and features of this invention become clear from the following description of preferred embodiments with reference to the attached Figures[.]:

[0013] Figure 1 shows a perspective view of a conversion unit as claimed in the invention; and

[0014] Figure 2 shows a plan view of four groups of lines of electromagnetic radiation which can be produced using the conversion unit as shown in Figure 1 in a predefinable three-dimensional area.

Detailed Description of the Invention

[0015] First, reference is made to Figure 1. The sample embodiment of a conversion unit 1 as [claimed] depicted in the invention, as shown in Figure 1, is composed of four identical

refractive elements 2. In the embodiment shown, the refractive elements 2 are each of the same size and each have a planar quadratic entry surface for the electromagnetic radiation, the four entry surfaces being located bordering one another such that the four quadratic planar entry surfaces of the refractive elements form a continuous square.

[0016] One optically functional interface 3, which is used as the exit surface for the electromagnetic radiation, made for example as a laser beam is opposite the planar entry surface of each of the refractive elements 2. In the embodiment shown, the optically functional interfaces 3 are each divided into four segments 4[, in]. In the embodiment shown, the segments being chosen such that the refractive element 2 represents a regular four-sided pyramid with curved side surfaces. The curvature of the segments 4 of the optically functional interface 3 is chosen in the embodiment shown such that the segments 4 opposite one another are sections of the same cylinder jacket. Here the cylinder axes of adjacent segments 4 are perpendicular to one another at the same time. Each of the refractive elements 2 thus [comprises] include, in the embodiment shown, an optically functional interface 3 which is composed of four segments 4 which are used as cylinder lenses. These segments 4 which are used as cylinder lenses touch one another at the tip of the aforementioned regular polygonal pyramid with curved side surfaces.

[0017] With corresponding transparency of the conversion unit, shown in Figure 1, to the electromagnetic radiation incident on the conversion unit 1, in the three-dimensional area which is located preferably at the distance of the focal length of the cylinder lens-like segment 4 from the conversion unit, there is an arrangement of groups 5 of lines which is apparent from Figure 2. Each of the groups 5 of lines [comprises] include two lines 6, 7 which cross one another at an angle of 90°. Each of the lines 6 and 7 represents a combined focal line of two segments 4 of an optically functional interface 3 of one of the refractive

elements 2, the two segments 4 being opposite one another. The vertical position of the cylinder axes of adjacent segments 4 of refractive elements 2 yields the cross shape of each of the groups 5 of lines. In particular, the right angle between the lines 6 and 7 follows from the cylinder axes of adjacent segments 4 being perpendicular to one another.

[0018] If the cylinder axes of adjacent segments are not perpendicular to one another, there is a group of lines in which the individual lines cross at an angle which is not equal to a right angle. It is possible as [claimed] <u>depicted</u> in the invention to choose different geometries of the individual segments. For example, aspherical cylinder geometries can be used, or even largely free-form surface geometries. It is also possible to divide the optically functional interfaces into more or less than four segments.

[0019] In this way, not only crossed groups of lines which according to Figure 2 overall yield a grid, but also lines which yield a triangle or lines which yield a polygon and which are then combined with the corresponding other groups of lines into patterns can be produced. It is also possible to execute the individual lines as curved lines, depending on the geometrical configuration of the individual segments or the individual optically functional interfaces of the conversion unit.

[0020] Furthermore, it is possible to produce for example grid-shaped groups of lines which then become apparent only as an orthogonal grid structure when the laser radiation passing through the conversion unit in the given three-dimensional area is incident on a curved surface of a workpiece[, for example]. One such structure which appears as an orthogonal grid structure in projection onto a curved surface could be used, for example, within the framework of machining processes on the aforementioned workpiece. In particular, a robot which shapes a workpiece could remove material in a controlled manner on the workpiece until the light passing through from the conversion unit to the workpiece yields an orthogonal planar grid. [Exactly in] <u>In</u> this case,

[does] the workpiece [have] has the desired curved surface on which the projected groups of lines yield an orthogonal planar grid.

[0021] It is furthermore possible for the device for producing lines or groups of lines to be integrated into a robot which machines workpieces so that both a laser light source and also a corresponding conversion unit are encompassed by the robot. Alternatively, there can be a separate device for producing lines or groups of lines which [comprises] includes a laser light source and a conversion unit and accordingly must be arranged at a given interval to the workpiece which is to be machined by the robot.

#4/a

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Vitalij LISSOTSCHENKO and Alexei MIKHAILOV

Attn: PCT Branch

Serial No.: **Not yet awarded**

Filed :

For : **PRODUCTION OF LINES OF LIGHT AS AN AID TO POSITIONING A ROBOT**

PRELIMINARY AMENDMENT

Commissioner of Patents and Trademarks
Washington, D.C. 20231

ATTN: PCT BRANCH

Sir:

Please amend the above-identified application as follows:

In the Claims:

Cancel claims 1-11 and kindly replace them with the claims (12-22) on the attached addendum.

Remarks

The claims have been amended to place them in conformance with U.S. practice and to eliminate multiple dependencies. No new matter has been added.

Respectfully submitted,

Stewart L. Gitler
Reg. 31,256

January 10, 2002

Hoffman, Wasson & Gitler, P.C.
2361 Jefferson Davis Highway
Suite 522
Arlington, Virginia 22202
(703)415-0100

Attorney Docket: A-7751.PAM/eb

What is claimed is:

12. A device for producing at least one line, or a group of lines of electromagnetic radiation of the optical spectral range in a preselectable three-dimensional area, the at least one line, or the group of lines, are used as positioning aids, or geometry detection aids, the device comprising at least one conversion unit which is at least partially transparent to the electromagnetic radiation used and which can convert the electromagnetic radiation passing through it, such that the electromagnetic radiation forms the at least one line, or the group of lines in a given three-dimensional wherein the conversion unit comprises at least one refractive element, by refraction of the radiation passing though the at least one conversion unit on at least one optically functional interface of the refractive element the at least one line or the group of lines being formed in a given three-dimensional area.

13. The device as claimed in claim 12, wherein the at least one optically functional interface of the at least one refractive element has a freely selectable configuration which is suitable for the at least one line or the group of lines to be produced.

14. The device as claimed in claim 12, wherein the at least one optically functional interface of the at least one refractive element is divided into segments.

15. The device as claimed in claim 14, wherein the segments have the same size and have an identical shape.

16. Device as claimed in claim 14, wherein the segments have a cylinder lens geometry, and wherein two groups of the segments, with cylinder axes of cylinder geometry, and the axes of the two groups being perpendicular to one another.

17. The device as claimed in claim 16, wherein the cylinder lens geometry of the segments is a spherical or an aspherical cylinder lens geometry.

18. The device as claimed in claim 12, wherein the at least one line is a straight line or a curved line.

19. The device as claimed in claim 12, wherein the group of lines can be crosses, triangles, polygons or lattices, and the at least one line, which form the group of lines can be on top of one another at a right angle or at an angle which differs from a right angle.

20. The device as claimed in claim 12, wherein the at least one line or the group of lines are curved such that they image a planar orthogonal lattice, when they encounter a curved surface of a workpiece in a given three-dimension area on the latter.

21. The device as claimed in claim 12, wherein the device further comprises a laser light source for producing the electromagnetic radiation.

22. Robots for machining of workpieces comprising a device as claimed in claim 12.

WO 01/03892 PCT/EP00/05934

Translation

PRODUCING LINES OF LIGHT FOR POSITIONING ASSISTANCE FOR ROBOTS

This invention relates to a device for producing lines or groups of lines of electromagnetic radiation of the optical spectral range in a definable area of space, and the lines or groups of lines can be used as positioning aids or geometry detection aids, comprising at least one conversion unit which is at least partially transparent to the electromagnetic radiation used, and which can convert the electromagnetic radiation passing through it, especially coherent radiation or laser radiation, such that the electromagnetic radiation forms at least one line or group of lines in a given three-dimensional area.

A device of this type is used for example to give to a robot a positioning aid for machining of a workpiece or to make available to the robot a recognition aid for the contour or the geometry of a workpiece. Generally the electromagnetic radiation is laser light which passes through the conversion unit into the stipulated three-dimensional area located for example on the workpiece such that on the workpiece for the robot, recognizable groups of lines are copied in the form of a planar orthogonal grid. Using these groups of lines made for example as grids the robot is enabled to machine the workpiece at given points.

Conversion units in the prior art are diffractive elements such as holograms which can diffract parts of the laser light

penetrating the conversion unit such that in the given three-dimensional area for example on the workpiece, lines or for example grid-shaped groups of lines form. One defect in the embodiment of the conversion unit using diffractive elements is that a substantial portion of the electromagnetic radiation is diffracted into undesirable orders so that generally far less than 50% of the electromagnetic radiation incident on the conversion unit contributes to producing lines or groups of lines. Furthermore, when the conversion unit is equipped with diffractive elements it is disadvantageous that only very small widening angles can be achieved so that only in a relatively small range of solid angles behind the conversion unit can lines or groups of lines be produced.

The object of this invention is to devise a device of the initially mentioned type which is made to be more efficient.

This is achieved as claimed in the invention in that the conversion unit comprises at least one refractive element, by refraction of the radiation passing through the conversion unit on at least one optically functional interface of the refractive element at least one line or group of lines is formed in the given three-dimensional area. When using a refractive element, much higher efficiencies of almost 100% can be achieved. Furthermore, refractive elements make it possible to much more dramatically broaden the electromagnetic radiation incident on the conversion unit so that the desired lines or groups of lines can be formed in an essentially larger range of solid angles behind the conversion unit.

To do this, the optically functional interface of at least one refractive element can have a freely selectable configuration which is suitable for the lines or line groups to be produced. It is for example possible to divide the optically functional interface of at least one refractive element into segments. In this case the segments can have the same size and can be shaped to be identical.

According to one preferred embodiment of this invention the individual segments can have a cylinder lens geometry, there being preferably two groups of segments with cylinder axes of cylindrical geometry perpendicular to one another. The cylinder lens geometry of the individual segments can be a spherical or an aspherical cylinder lens geometry. Especially in the choice of these cylinder lens geometries is it possible to widen the electromagnetic radiation passing through the conversion unit behind the latter into a solid angle of up to or even more than 180°. For example, groups of crossed lines can be formed by the arrangement of individual segments of the optically functional interface as cylinder lens segments with cylinder axes perpendicular to one another and can form a grid-like structure, as for example a planar orthogonal grid with a correspondingly array-like arrangement of the refractive elements.

It is possible as claimed in the invention for the produced lines to be straight or even curved lines. Furthermore it is possible for the generated groups of lines to be crosses, triangles, polygons or grids, and the lines which form the

individual groups of lines can be at a right or an non-right angle to one another.

According to one preferred embodiment of this invention, the generated lines or groups of lines are curved such that upon incidence on a curved surface of a workpiece in a given three-dimensional area on this workpiece they form a planar structure, especially a planar, orthogonal grating. It is for example conceivable that a machining robot machines the workpiece or for example removes material from the workpiece with the aid of the aforementioned inherently curved grid structure until the sensors of the robot detect that the line structure which is incident on the machined curved surface of the workpiece forms a planar orthogonal grid. The conversion unit encompassed by the device as claimed in the invention thus causes distortion of the traversing electromagnetic radiation which is distorted by a correspondingly curved workpiece such that a clearly detectable structure like a planar orthogonal grid is formed.

It is possible for the device to comprise a source for producing electromagnetic radiation, especially a laser light source. The device together with the laser light source can be used either as a separate unit or can for example be installed in a corresponding robot for machining of workpieces.

It is also possible to use one such device for process monitoring for example to monitor a welding process, here especially an application in conjunction with CMOS cameras seeming to be suitable, because these CMOS cameras have much higher dynamics so that among others both the welding point and

also its vicinity can be better recognized, so that for example the lines or groups of lines imaged on the workpiece to be welded can be better recognized by the welding unit or the process monitoring unit. Other possible applications of a device as claimed in the invention are in the area of surface analysis or three-dimensional assignment, especially tracking of a system.

Other advantages and features of this invention become clear from the following description of preferred embodiments with reference to the attached Figures.

Figure 1 shows a perspective view of a conversion unit as claimed in the invention;

Figure 2 shows a plan view of four groups of lines of electromagnetic radiation which can be produced using the conversion unit as shown in Figure 1 in a predefinable three-dimensional area.

First, reference is made to Figure 1. The sample embodiment of a conversion unit 1 as claimed in the invention as shown in Figure 1 is composed of four identical refractive elements 2. In the embodiment shown the refractive elements 2 are each of the same size and each have a planar quadratic entry surface for the electromagnetic radiation, the four entry surfaces being located bordering one another such that the four quadratic planar entry surfaces of the refractive elements form a continuous square.

One optically functional interface 3 which is used as the exit surface for the electromagnetic radiation made for example as a laser beam is opposite the planar entry surface of each of the refractive elements 2. In the embodiment shown the optically

functional interfaces 3 are each divided into four segments 4, in the embodiment shown the segments being chosen such that the refractive element 2 represents a regular four-sided pyramid with curved side surfaces. The curvature of the segments 4 of the optically functional interface 3 is chosen in the embodiment shown such that the segments 4 opposite one another are sections of the same cylinder jacket. Here the cylinder axes of adjacent segments 4 are perpendicular to one another at the same time. Each of the refractive elements 2 thus comprises in the embodiment shown an optically functional interface 3 which is composed of four segments 4 which are used as cylinder lenses. These segments 4 which are used as cylinder lenses touch one another at the tip of the aforementioned regular polygonal pyramid with curved side surfaces.

With corresponding transparency of the conversion unit shown in Figure 1 to the electromagnetic radiation incident on the conversion unit 1, in the three-dimensional area which is located preferably at the distance of the focal length of the cylinder lens-like segment 4 from the conversion unit there is an arrangement of groups 5 of lines which is apparent from Figure 2. Each of the groups 5 of lines comprises two lines 6, 7 which cross one another at an angle of 90°. Each of the lines 6 and 7 represents a combined focal line of two segments 4 of an optically functional interface 3 of one of the refractive elements 2, the two segments 4 being opposite one another. The vertical position of the cylinder axes of adjacent segments 4 of refractive elements 2 yields the cross shape of each of the

groups 5 of lines. In particular the right angle between the lines 6 and 7 follows from the cylinder axes of adjacent segments 4 being perpendicular to one another.

If the cylinder axes of adjacent segments are not perpendicular to one another, there is a group of lines in which the individual lines cross at an angle which is not equal to a right angle. It is possible as claimed in the invention to choose different geometries of the individual segments. For example, aspherical cylinder geometries can be used, or even largely free-form surface geometries. It is also possible to divide the optically functional interfaces into more or less than four segments.

In this way, not only crossed groups of lines which according to Figure 2 overall yield a grid, but also lines which yield a triangle or lines which yield a polygon and which are then combined with the corresponding other groups of lines into patterns can be produced. It is also possible to execute the individual lines as curved lines, depending on the geometrical configuration of the individual segments or the individual optically functional interfaces of the conversion unit.

Furthermore, it is possible to produce for example grid-shaped groups of lines which then become apparent only as an orthogonal grid structure when the laser radiation passing through the conversion unit in the given three-dimensional area is incident on a curved surface of a workpiece, for example. One such structure which appears as an orthogonal grid structure in projection onto a curved surface could be used for example within

the framework of machining processes on the aforementioned workpiece. In particular, a robot which shapes a workpiece could remove material in a controlled manner on the workpiece until the light passing through from the conversion unit to the workpiece yields an orthogonal planar grid. Exactly in this case does the workpiece have the desired curved surface on which the projected groups of lines yield an orthogonal planar grid.

It is furthermore possible for the device for producing lines or groups of lines to be integrated into a robot which machines workpieces so that both a laser light source and also a corresponding conversion unit are encompassed by the robot. Alternatively, there can be a separate device for producing lines or groups of lines which comprises a laser light source and a conversion unit and accordingly must be arranged at a given interval to the workpiece which is to be machined by the robot.

Claims

1. Device for producing lines (6, 7) or groups (5) of lines of electromagnetic radiation of the optical spectral range in a preselectable three-dimensional area, and the lines (6, 7) or groups (5) of lines can be used as positioning aids or geometry detection aids, comprising at least one conversion unit (1) which is at least partially transparent to the electromagnetic radiation used and which can convert the electromagnetic radiation passing through it, especially coherent radiation or laser radiation, such that the electromagnetic radiation forms at least one line (6, 7) or group (5) of lines in a given three-dimensional area, characterized in that the conversion unit (1) comprises at least one refractive element (2), by refraction of the radiation passing though the conversion unit (1) on at least one optically functional interface (3) of the refractive element (2) at least one line (6, 7) or group (5) of lines being formed in a given three-dimensional area.

2. Device as claimed in claim 1, wherein the optically functional interface (3) of at least one refractive element (2) has a freely selectable configuration which is suitable for the lines (6, 7) or groups (5) of lines to be produced.

3. Device as claimed in one of claims 1 or 2, wherein the optically functional interface (3) of at least one refractive element (2) is divided into segments (4).

4. Device as claimed in claim 3, wherein the segments (4) have the same size and have preferably an identical shape.

5. Device as claimed in one of claims 3 or 4, wherein the individual segments (4) have a cylinder lens geometry, there being preferably two groups of segments (4) with cylinder axes of cylinder geometry, the axes being perpendicular to one another.

6. Device as claimed in claim 5, wherein the cylinder lens geometry of the individual segments (4) is a spherical or an aspherical cylinder lens geometry.

7. Device as claimed in claim 1 to 6, wherein the generated lines (6, 7) can be straight or curved lines.

8. Device as claimed in one of claims 1 to 7, wherein the generated groups (5) of lines can be crosses, triangles, polygons, grids or the like, and the lines (6, 7) which form the individual groups (5) of lines can be on top of one another at a right angle or at an angle which differs from a right angle.

9. Device as claimed in one of claims 1 to 8, wherein the generated lines (6, 7) or the generated groups (5) of lines are curved such that they image a planar structure, especially a

planar orthogonal grid, when they encounter the curved surface of a workpiece in a given three-dimension area on the latter.

10. Device as claimed in one of claims 1 to 9, wherein the device comprises a source for producing the electromagnetic radiation, especially a laser light source.

11. Robots for machining of workpieces comprising a device as claimed in one of claims 1 to 10.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
18. Januar 2001 (18.01.2001)

PCT

(10) Internationale Veröffentlichungsnummer
WO 01/03892 A1

(51) Internationale Patentklassifikation[7]: B25J 9/16, G02B 27/12, G01B 11/00

(21) Internationales Aktenzeichen: PCT/EP00/05934

(22) Internationales Anmeldedatum: 27. Juni 2000 (27.06.2000)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität:
199 32 590.1 13. Juli 1999 (13.07.1999) DE

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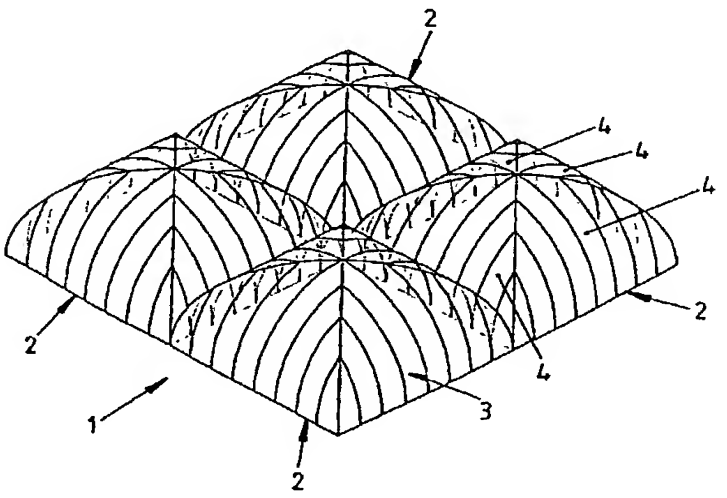
[Fortsetzung auf der nächsten Seite]

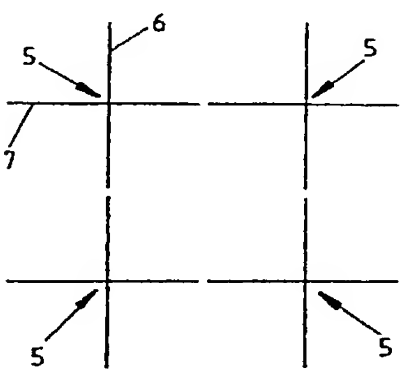
(54) Title: PRODUCTION OF LINES OF LIGHT AS AN AID TO POSITIONING A ROBOT

(54) Bezeichnung: ERZEUGUNG VON LICHTLINIEN ZUR POSITIONIERHILFE FÜR ROBOTER



(57) **Abstract:** The refractive converter unit (1) is 100 % effective compared with holograms and comprises four refractive elements (2), each of which consists of a regular four-sided pyramid provided with lateral surfaces (4) having a curved, spherical or aspherical outer cylindrical envelope. Triangles, polygons and grid-like structures can be used to generate curved lines for a processing robot. Four crosses (5) are generated by a laser light source. A CMOS camera can be used as a geometrical detection aid in order to monitor a welding process.

(57) **Zusammenfassung:** Die gegenüber Hologrammen 100 % effektive refraktive Umwandlungseinheit (1) besitzt vier refraktive Elemente (2) mit jeweils einer regulären vierseitigen Pyramide mit gekrümmten sphärischen oder asphärischen Zylindermantel Seitenflächen (4). Dreiecke, Vielecke und Gitter sind möglich zur Erzeugung auch gekrümmter Linien für einen Bearbeitungsroboter. Eine Laserlichtquelle erzeugt damit vier Kreuze (5). Schweissprozessüberwachung in Verbindung mit einer CMOS Kamera als Geometriedetektionshilfe.



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#6

Declaration and Power of Attorney for Patent Application
Erklärung für Patentanmeldungen mit Vollmacht

German Language Declaration

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ERZEUGUNG VON LICHTLINIEN ZUR POSITIONIERHILFE FÜR ROBOTER

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

PRODUCTION OF LINES OF LIGHT AS AN AID TO POSITIONING A ROBOT

deren Beschreibung hier beigefügt ist, es sei denn (in diesem Falle Zutreffendes bitte ankreuzen), diese Erfindung

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the specification of which is attached hereto unless the following box is checked.

☒ was filed on January 11, 2002 as United States Application Number or PCT International Application 10/030,084 and was amended on _____ (if applicable).

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Prior Foreign Applications
(Frühere ausländische Anmeldungen)

(Number) (Nummer)	(Country) (Land)	(Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	Priority Not Claimed Priorität nicht beansprucht
✓ 199 32 590.1	Germany	13/07/1999	☐
PCT/EP00/05934	PCT	27/06/2000	☐

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(Application No) (Aktenzeichen)	(Filing Date) (Anmeldetag)	(Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)

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